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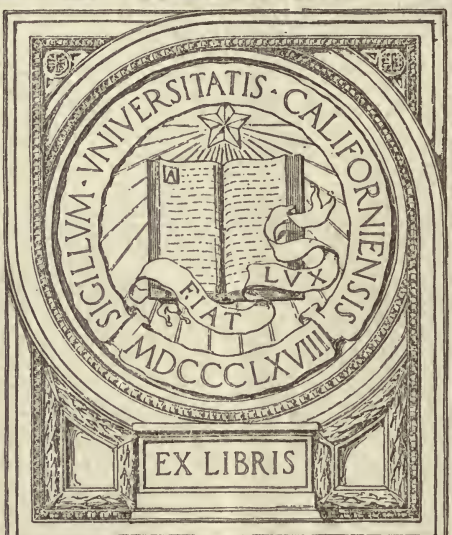

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BULLETIN No. 2.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

ADVISORY COUNCIL.

MEMORANDUM

ON

CUTTING LUBRICANTS

AND

COOLING LIQUIDS,

AND ON

SKIN DISEASES PRODUCED BY LUBRICANTS.

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PREFATORY NOTE.

This bulletin has been prepared by a Committee of the Department in connection with the survey of the field for research on Lubricants and Lubrication, upon which the Committee is engaged. It appeared to the Advisory Council that the paper embodied most of the existing knowledge on the subject in a manner which might be of considerable service to Engineers and other users of Cutting Lubricants who have not at present either time or opportunity to make a special study of the subject.

It is not claimed that the bulletin contains new knowledge, but it is felt that it furnishes a large amount of useful information which will be new to many users of cutting lubricants and likely to increase the efficiency of production in operations concerned with the cutting of metals, and for this reason it has been decided to publish it, after submitting it for criticism to leading engineering firms, and, through the Ministry of Munitions, to the Heads of Departments in the Ministry concerned with the subject. The Advisory Council desire to express their indebtedness to those who have kindly assisted by criticism and by furnishing additional information of value which has been incorporated in the document.

The first of the two parts into which the information is divided deals with cutting lubricants and cooling liquids, and has been prepared by Mr. T. C. Thomsen, a member of the Lubricants Committee; the second, dealing with skin diseases produced by lubricants, has been prepared by Dr. J. C. Bridge, H.M. Medical Inspector of Factories, Home Office. It is hoped that the information, now given a wider publicity, may be found to be of service to the Technical and also to the Administrative and Welfare Departments of Engineering Works.

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MEMORANDUM ON CUTTING LUBRICANTS AND COOLING LIQUIDS AND ON SKIN DISEASES PRODUCED BY LUBRICANTS.

Part I.—Cutting Lubricants and Cooling Liquids.

1. Cutting Lubricants and Cooling Liquids are oils or emulsions used in connection with the cutting of metal. They possess lubricating and cooling properties in different degrees, and the various classes into which they are divided may be defined as follows:—

Soluble Oils.—The products known as soluble oils are oily liquids which form an emulsion when mixed with water.

Soluble Compounds, also known as Cutting Compounds.—Soluble Compounds or Cutting Compounds are greasy pastes which form an emulsion when mixed with water.

Cutting Emulsions.—Cutting emulsions are aqueous emulsions formed by mixing soluble oils or soluble compounds with water.

Cutting Oils.—Cutting Oils are oils such as Lard Oil, Rape Oil, or Mineral Oils, or a mixture of such oils free from water and from soap. These oils do not ordinarily form emulsions with water.

2. Cutting lubricants and cooling liquids are used for the purpose of:—

(*a*) Cooling.

(*b*) Lubrication.

(*c*) To produce smooth finish.

(*d*) To wash away chips.

(*e*) To protect the finished product from rust or corrosion.

(a) *Cooling.*—During operation the heat developed warms not only the tool, but also the material which is being machined. On cooling the latter will contract, and the dimensions will differ from the measurements taken during the process of machining.

The importance of properly cooling the product is, therefore, obvious, particularly under high-speed conditions and with materials, such as aluminium, which have a high co-efficient of expansion.

If the tool heats too much the cutting edge will wear rapidly. The heat generated at the point of the tool is conducted into the body of the tool; if the tool is of large section the heat is more readily dissipated than is the case with a tool of light section. Efficient cooling of the tool edge reduces wear and enables a greater output to be obtained. This is most apparent with high-speed steel, the gain in cutting speed on steel and wrought iron being from 30 per cent. to 40 per cent. and on cast iron from 16 per cent. to 20 per cent. Efficient cooling of the shavings on the side not in contact with the tool is particularly important with tough material, helping to reduce the friction produced by the shavings rubbing against the nose of the tool.

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(b) *Lubrication.*—Lubrication is of little importance where the manufactured article is made of brittle material, as the material is removed in the form of powder or fine chips. In the case of cast iron considerable advantage may be obtained by using an aqueous emulsion in order to wash the dust away from the working parts and to prevent its dispersal in the air.

Lubrication is very important where the metal is tough, the material being removed in the form of spiral shavings, which grind their way over the nose of the tool. The character of the chips or shavings produced will depend upon the form given to the tool by grinding, and also upon the angle at which it is used.

The heavier the cut the greater will be the metallic friction and the greater the necessity for lubricating the nose of the tool, otherwise the shavings will produce great friction, resulting in rapid destruction of the tool and in rough finish.

(c) *To Produce Smooth Finish.*—When the requirements of cooling and lubrication are satisfied the product will receive a good finish. It is also desirable that the cutting oil should have sufficient fluidity to ensure a rapid stream being concentrated when required. Where a perfect finish is desired, experience has shown that cutting oils possessing great oiliness must be applied. For this reason various animal or vegetable oils, or rich mixtures of such oils with mineral oils, are usually employed. Some engineers find vegetable oils possessing great oiliness, such as rape or cotton seed oil, preferable to either mineral or animal oils in producing a very smooth finish. Dies, taps, reamers and form tools have a longer life when used on tough steel if a cutting oil is employed in place of an emulsion prepared from a compound or soluble oil. For finish boring, rifling, &c., a mixture of castor oil and mineral cleaning oil (gravity about 860-890) in the proportion of 3 parts of cleaning oil to 1 of castor oil has been used with good results; although those oils do not form a homogeneous mixture, the addition of an equal volume of turpentine substitute (white spirit) causes perfect solution to take place, and is said to be advantageous for finish-turning on guns and hard material.

(d) *To Wash Away Chips.*—Frequently the washing away of chips is quite an important function of the cutting lubricant or cooling liquid, particularly in cases of deep drilling, as in drilling rifle barrels and the like, also in most milling operations.

If the cutting emulsion is used too weak it will not carry away with it the minute particles of metal and scale which may prove detrimental to the machine tool.

In the boring of deep holes, gun-tubes, &c., a solution of sodium carbonate (50 lbs.) and soft soap (25 lbs.) in water (200 gallons) has been found to give very satisfactory results.

In solid deep-hole boring, where cutting emulsions are used, it is sometimes found that the emulsion, in filtering through the chips in the bore, becomes changed in character in such a manner as to lose some of its lubricating quality.

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(e) *To Protect Finished Product from Rust and Corrosion.*—Good cutting oils used "straight" (*i.e.*, not emulsified with water) will not cause rusting.

Cutting oils containing fixed oils (animal or vegetable oils) such as lard oil, with a large percentage of free fatty acid, will cause verdigris on brass parts. Vegetable oils containing only a small percentage of free fatty acid, such as rape oil, when employed in cutting oils do not produce verdigris unless the oils are rancid.

Cutting emulsions made up from cutting compounds or soluble oils and water cause rusting if they are used too weak, or if they contain acid. Water from some sources contains considerable quantities of sodium chloride (common salt), which is most destructive to the emulsion; in such cases a supply of water free from salt must be used.

Emulsions of oil and water are not stable in the presence of even minute quantities of acid. The acid causes separation of the emulsion into layers of oil and water, the water is circulated by the pump and causes rusting of the work. To a limited extent the emulsion can be reformed by adding a calculated quantity of ammonia sufficient to neutralise the acid, but any excess of alkali may facilitate corrosion of the metal being worked.

The admixture with a soluble oil of paraffin oil (5 per cent. or more) prior to the addition of water has been reported to give good results; a thin film of paraffin oil forms on the top of all standing oil in barrels and tanks and prevents the access of air, similarly a thin film of paraffin oil forms over machined parts, machines and tools which prevents gumming and rust. It should be noted, however, that the addition of paraffin to a soluble oil reduces its lubricating and emulsifying properties.

Emulsions must not be made by mixing soluble oils or cutting compounds with hard water owing to the precipitate caused by the action of the calcium and magnesium salts in such water. Soft water must be used, which may be either rain water or distilled water, or, if neither of these is available, the hard water must be softened by chemical means.

Selection of Cutting Lubricants.

3. Before selecting the correct grade of cutting lubricants it is necessary to consider several important factors such as:—

(*a*) Cutting speed and depth of cut.
(*b*) The material under manufacture.
(*c*) The system of application of the lubricant or emulsion.
(*d*) The production of skin diseases (*see* part II., page 7).

(a) *Cutting Speed and Depth of Cut.*

Low Speed and Shallow Cut.—Low speed and shallow cut requires little cooling and little lubrication.

Low Speed and Heavy Cut.—Low speed and heavy cut, particularly if the material is tough, demands a cutting lubricant possessing great oiliness.

High Speed and Shallow Cut.—High speed and shallow cut demands a cutting medium with great cooling properties, consequently emulsions are frequently used. Where a perfect finish is desired, low viscosity cutting oils are used "straight."

Where the speeds are particularly high emulsions only should be used, as otherwise there will be excessive heating of the tools and of the product.

Turpentine substitute ("white spirit") is a satisfactory lubricant for aluminium, but it possesses the undesirable quality of inflammability, and if employed must be used with care on this account.

A mixture of petroleum burning oil (paraffin oil) with lard oil or other cutting oil for high-speed work in connection with aluminium is also dangerous and has led to several fires. It is better to use cutting emulsions which possess the necessary cooling properties and are not inflammable.

High Speed and Heavy Cut.—High speed and heavy cut demands a cutting lubricant with great cooling as well as lubricating properties, so that heavily compounded cutting lubricants of low viscosity must be used. Low viscosity is necessary to give good cooling effect, and heavy compounding with animal or vegetable oils is requisite so as to lubricate the tools and shavings effectively and prevent wear as far as possible. For tough material and heavy cuts an emulsion containing 15 per cent. to 20 per cent. of a vegetable oil has been reported to be satisfactory.

(b) *Material under Manufacture.*—The influence of the material upon the choice of cutting oil has already been referred to (*see* Section 2, page 1).

Where material is brittle, cutting emulsions are nearly always used.

Where the material is tough, but where the speeds are high and the cut light, cutting emulsions are also frequently employed; but where the material is tough and the cut heavy it is necessary to employ cutting lubricants used "straight" and containing a percentage of animal or vegetable oils (ranging from 10 per cent. to 50 per cent.) or consisting entirely of such oils.

With automatic screw-cutting machines, emulsions have been found in some cases to form a deposit in the working parts of the machines. This may be avoided by the employment of "straight" oils, but in view of the present scarcity of oil, it is advisable in the national interest to use emulsions wherever possible.

The amount of soluble oil or soluble compound used for preparing the cutting emulsion varies from 2½ per cent. to 20 per cent., the richer mixtures being used for severe conditions, and the weaker mixtures for light duties or for materials such as brass and aluminium where there is no danger of rusting.

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(c) *System of Application.*

The cutting lubricant may be applied by hand by a drop-feed system or by some system employing gravity or pumping.

In large machine shops the cutting oil is sometimes circulated through pipes throughout the works, returning through other pipes from the machine tools to a central tank.

Group systems with central tanks are excellent where one mixture is used for all machines on the circuit.

Return pipes should be large, and should be arranged for easy access for cleaning; in large systems isolating valves should be employed to sectionise the system; efficient strainers should be fitted on all return pipes and pump sections and should be cleaned daily. Tanks as a rule should be cleaned out every 4 weeks and return pipes every 4 months. Any scum formed should be skimmed off the tanks daily.

It is important both with this system and where machine tools have individual pumps that the pump's suction should be always covered so that air cannot be drawn into circulation, since aeration of the circulating medium has a strong oxidising effect upon the oil or emulsion. The important point to keep in mind in regard to the system of application of the lubricant is that where the oil or emulsion is circulated over and over again, it is exposed to the oxidising effect of air and to admixture with dust and dirt from the machine shop.

A certain amount of oil or emulsion is always splashed away from the machine tools in the form of spray, and is lost notwithstanding precautions taken by the use of splash guards; the loss of oil depends very largely upon the viscosity of the cutting medium.

Physical and Chemical Points of Interest.

4. *Cutting Oils.*—The mineral oils, which are best suited to be used as cutting lubricants, either alone or mixed with animal or vegetable oil are mineral oils, preferably of pale colour, of low viscosity, ranging from 100 seconds to 200 seconds Redwood at 100° F. The lower viscosity oils may be used for high-speed conditions and oils with higher viscosity may be used for slow-speed conditions. Of the animal oils used either alone or in admixture, tinged lard oil containing as much as 10 to 15 per cent. of free fatty acid is most frequently employed. Prime lard oil is almost free from acid; it is much more expensive than tinged lard oil, but is less inclined to gum under severe conditions (heavy cut and high speed).

Lard oil congeals in cold weather, so that, wherever possible, a mixture of lard oil and low cold test mineral oil is to be preferred on account of greater fluidity in the cold. Experience has proved that most cutting lubricants containing vegetable oils, particularly if they are heavily blown (*i.e.*, thickened by oxidation) are liable to produce gummy deposits in circulation systems.

These deposits interfere with the proper operation of the machine, and necessitate frequent cleaning of the machines, which not only increases the costs, but also decreases the output.

Cotton seed oil oxidises more readily than rape oil, and should not be used in the manufacture of cutting lubricants that are to be used in a circulation system. Animal oils are not so easily oxidised in a circulation system as are vegetable oils.

Experience shows that lard oil only produces deposits in circulation systems under severe operative conditions when the percentage of free fatty acid exceeds, say, 10 per cent.

When oils of low volatility are used a certain proportion of the oil is evaporated by the heat produced in the work; this is objectionable on account of the smoke and fumes created. Where cutting emulsions are used steam only is produced.

Cutting oils are nearly always used " straight," *i.e.*, without admixture of water.

Certain cutting oils containing at least 5 per cent. of free fatty acid and preferably more than 20 per cent. of saponifiable oil (animal or vegetable oil) may either be used " straight " or in the form of cutting emulsions. They will emulsify with water to which the requisite amount of alkali (soda ash, borax, &c.) has been added.

Soluble Oils and Soluble Compounds.—Soluble oils are prepared by dissolving a soap (usually less than 20 per cent.) in a mixture of mineral oil (usually less than 70 per cent.) and saponifiable oil (usually more than 15 per cent.).

The saponifiable oils used in making the soap are either of animal or vegetable origin such as lard oil or other olein from animal fat, whale oil, wool grease, castor oil, sulphonated castor oil, rape oil, cotton seed oil, resin, resin oil, &c., and the oils are saponified by means of caustic soda or caustic potash.

Some soluble oils or compounds contain a small percentage of alcohol or ammonia, which causes the emulsion to form more readily.

When soluble oils containing ammonia are stored for several months in wooden barrels, the ammonia is sometimes absorbed by the barrel, and the oil is no longer completely soluble in water.

With cutting emulsions made from soluble oils containing ammonia the ammonia volatilises under severe conditions of service, and a scum is produced on the surface of the emulsion which is objectionable, as it tends to clog the pipes in the circulation system, and by adhering to the swarf or chips causes considerable loss of oil. Soluble oils containing a large percentage of resin or resin oil have a tendency to cause gumming.

Soluble compounds are made on similar lines to soluble oils except that they contain 10 per cent. to 50 per cent. of water and are in a semi-solid and semi-emulsified condition. They are not so easily mixed with water as are soluble oils, and for this reason the latter are usually preferred.

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Part II.—Skin Diseases Produced by Lubricants.

1. Oil rashes are, generally speaking, of two kinds—the first is due to plugging of the small glands at the root of the hairs on the arms and legs of workers, the second to mechanical injury to the skin produced by metallic particles suspended in the cutting lubricant.

(a) *Plugging of the Glands of the Hair Follicles.*

Primarily this is purely mechanical; a mixture of oil and dirt blocks the minute openings of these glands and sets up inflammation round the hair (folliculitis). The inflammation commenced in this way may lead on to suppuration or abscess formation (a boil). If many hairs are affected the arm presents an appearance of a crop of raised red spots (papules), with a black spot as a centre, or, if the inflammation has gone as far as suppuration (abscess formation), a yellow head.

(b) *Mechanical Injury to the Skin by Metallic Particles.*

Minute metallic particles suspended in the cutting lubricant may produce injury to the skin. This occurs chiefly on the hands, where two surfaces are rubbed together, *e.g.*, the skin between the fingers. Injury to the skin may also be produced on any part of the hands and arms by wiping with a cloth or rag while the hands or arms are coated with a film of fluid in which metallic particles are suspended. Injury to the skin allows germs to enter and causes septic infection.

2. *Prevention.*—(a) *Cleanliness of the Worker.*—Washing accommodation for workers in contact with oil must be on a liberal scale. Hot water, soap, and scrubbing brushes are essential. Workers should be instructed not to wipe their hands on rags, &c., before washing and to avoid washing their hands in the cutting compounds.

Ether soap, which dissolves oil, has been found useful in preventing inflammation of the hair follicles. Dusting the arms with a powder containing equal parts of starch and zinc oxide before commencing work prevents the action of the oil on the skin.

(b) *Cleanness of the Lubricant.*—Care must be taken in the handling of the constituents before blending that they have not undergone changes (*e.g.*, formation of free fatty acid).

Constant removal of metal particles is necessary to avoid injury to the skin. Filtration, such as is provided on the machines and centrifugal action, are insufficient to remove the minute metal particles which may injure the skin. Where cutting oils (straight oils) are used, their viscosity can be diminished by heat sufficiently to allow the particles to sink without affecting their value as lubricants. This operation completely removes all metal particles. In other lubricants where such a procedure is impossible it is necessary constantly to change and renew the cutting lubricants.

(c) *Cleanness of the Machines.*—Frequent cleaning of the machines with the removal of all the old lubricant from all parts of the machine is essential.

3. *Addition of Disinfectants or Antiseptics to the Lubricants.*—Various antiseptics, carbolic acid (1 per cent. to 2 per cent.) being the most common, have been added to the lubricant to prevent rashes, and in the case of cutting emulsions 0·5 per cent. of disinfectants soluble in water have been used for this purpose. The results obtained have not been altogether satisfactory, and reliance cannot be placed upon such a method to prevent skin rashes.

4. *Sterilisation by Heat.*—It has been suggested to heat the cutting oil to 300° F. for a short period with a view to sterilising it as well as to increase its antiseptic or germicidal action.

Laboratory experiments in America have shown that used oil possesses rather marked germicidal effects, and in view of the fact that the used oil becomes heated during use attempts were made to determine whether heating new oil would also bestow upon it germicidal powers. Apparently, heating does produce such a change, but the temperature required is upwards of 125° C. The actual temperature required to produce this germicidal action in the oil has not yet been determined, but it has been recommended to mix new oil with the used oil before filtering and heating, so that the new oil would possess to some extent the germicidal power of the used oil.

5. *Removal of Workers with Septic Infection of the Hands.*—Workers whose hands become the seat of septic infection should not be allowed to work on machines, as they are liable to infect the oil with germs and so infect others.

6. *Treatment.*—(a) *Folliculitis Produced by Blocking of the Glands.*—As a general rule, frequent washing with soap and hot water is sufficient to produce a rapid cure. The skin may be subsequently dusted with zinc oxide and starch powder.

It has been found that where this is insufficient a mild antiseptic applied on lint has relieved the irritation and given good results.

(b) *Septic Infection of the Skin due to Cuts.*—Septic infection should be treated on general principles by the application of suitable antiseptic dressings.

7. *Susceptibility.*—Certain individuals appear to be particularly susceptible to the action of lubricants. Such persons when found should be removed from contact with oil.

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